Crude oil price variability and its impact on ethanol prices

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Abstract: The world annual biofuel production has exceeded 100 billion litres in 2009. The development of the biofuel production is partly influenced by the government support programs and partly by the development of oil prices. The main purpose of this paper is to analyze the statistical relationship between ethanol, gasoline and crude oil prices. We aim to check the correlation among these variables and to analyze the strength and direction of a possible linear relationship among the variables. We are interested in analyzing how each variable is related to another, so we evaluate the inter-relationship among the variables in the Vector Autoregression (VAR) and the Impulse Response Function (IRF). In order to achieve our goal, we first collected weekly data for each variable from January, 2000 to October, 2009. The results provide evidence of the cointegration relationship between oil and gasoline prices, but no cointegration between ethanol, gasoline and ethanol, oil prices. As a result, we used a VAR model on first differences. After running the Impulse Response Function, we found out that the impact of the oil price shock on the other variables is considerable larger than vice versa. The largest impact of oil price shock was observed on the price of gasoline.

Key words: biofuels, crude oil, gasoline, ethanol, cointegration

There has been a tremendous increase in the production of biofuels[1] in the recent years (Figure 1). The global production of biofuels reached 36 million tons, which is 62 billion liters, in 2007. Of this amount, around 85 percent of liquid biofuels is ethanol, while the remaining 15 percent is biodiesel. In 2009, the annual production of biofuels has already exceeded 100 billion litres. Incentives motivating the rise of the biofuel production come mainly from the government support programs.

Governments in the USA, the EU, and Brazil, as well as of other developed but also developing countries use

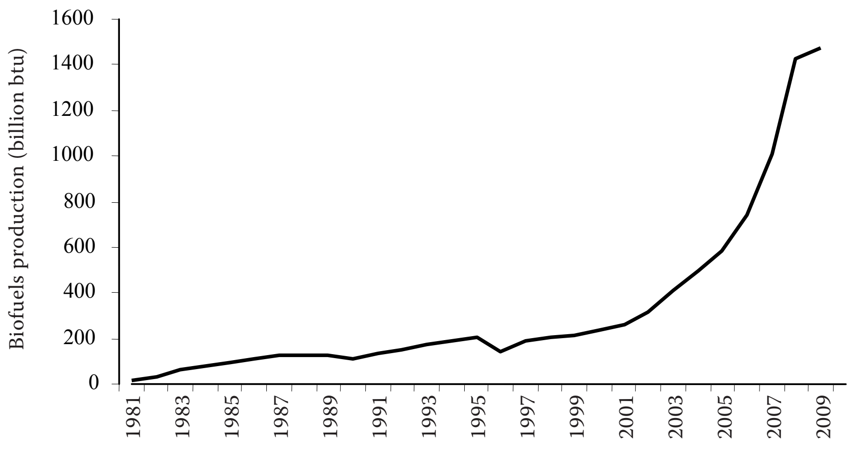

Figure 1. Development of the biofuel production

Source: Energy Information Administration (EIA)

[1]In this article, we will consider only ethanol and biodiesel, but biofuels in a wider sense are all fuels derived from the biomass provided by agriculture, forestry, or fishery, as well as from wastes of the agro-industry or food industry. Ethanol and biodiesel are used as the transportation fuels and they are almost perfect substitutes for fossil fuels produced from oil.

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a plethora of instruments to support the production of biofuels. Among the most important instruments, there belong the consumer excise-tax exemptions, the mandatory blending of biofuels and fossil fuels, import tariffs on biofuels, production subsidies for biofuel raw materials (e.g., energy crops) and biofuels themselves (grants, loan guarantees, tax incentives, etc.), subsidies for the R&D of new technologies.

In the EU, the biofuel directive (The Directive 2003/30/EC) sets that by 2010, the European Union should reach the reference target of 5.75% share of biofuels in the total transport fuel use. By year 2020, the European Union has a mandatory plan to achieve 10 percent share of biofuels in transport fuels. The individual member states can, in order to achieve the reference target, provide a tax concession for the support of the biofuel industry. The European Union also uses import tariff on the denaturated and undenaturated ethanol imports of 10.20 EUR per hl and 19.20 EUR per 1 hl respectively, which is an equivalent of 33.2 and 62.4 percent respectively in the ad valorem terms. The import tariff on biodiesel is 6.5 percent. The European Union also provides 45 EUR per hectare to farmers which produce the plants that are used for the production of biofuels (energy crops) or to generate heat or power. The set-aside[2] land can be used also for the production of the raw materials used for biofuels or for the generation of heat of power. The individual member states of the EU provide tax concessions. In average, the tax on biofuels is by 50 percent lower than the tax on fossil fuels.

The potential of renewable resources of the EU is considerable, nevertheless, the technological level is still not developed, compared to the fossil fuels. Therefore, their future development will depend to a great extent on the level of the supporting political mechanisms, but also on the level of scientific research and the resources put into it (Jenicek and Krepl 2009).

Due to the government support programs, the output of the biofuel industry increased significantly, what has led further to the decline of production costs as the economy of scale and learning by doing was realized.

Biofuels are almost perfect substitutes to fossil fuels. The market price of biofuels should therefore be strongly dependent on the market price for gasoline and diesel. De Gorter and Just (2008) describe the link between the price of gasoline and the price of ethanol. Perfect substitutes have the same prices, which means that $P_G = P_B$, where P_G is price of gasoline and P_B is the price of ethanol. However, one litre of ethanol has a lower energy content than one litre of gasoline, i.e. with one litre of ethanol, a car can travel a shorter distance than with one litre of gasoline, which means that in the energy terms $P_B = kP_G$, where in reality k is approximately 0.89. Because of the lower energy content, the price of one litre of ethanol is lower than the price of one litre of gasoline. The price of ethanol would be about 89 percent of the price of gasoline. When the excise tax is imposed on gasoline and ethanol, the post- tax prices become: $P_B + t = k(P_G + t)$, where t is an excise tax. In order to support the production of ethanol (biofuels in general), the tax exemptions are applied which leads to the following price equation: $P_B + t - te = k(P_G + t)$, where te is the tax exemption. The relationship between the price of gasoline and the price of ethanol becomes: $P_B = k \times P_G + kt - t + te$ and by rewriting, we get $P_B = kP_G - t(1 - k) + te$. From the previous equation, it follows that the price of ethanol decreases vis-à-vis the price of gasoline, the higher is the excise tax and the lower is the tax exemption. To increase the price of ethanol and to stimulate its production, the government can lower the excise tax on fuels in general and to increase the tax exemption on the use of biofuels.

A quantitative analysis of the relationship among ethanol, gasoline and crude oil prices has been largely neglected in the literature. There are, however, some exceptions.

O'Brien and Woolverton (2009) examined the statistical relationship between the ethanol prices and the gasoline prices. They find a positive correlation between the ethanol price series and the oil price series amounting to 83%. According to Obrien and Woolverton, a 10% increase in the Midwest gasoline prices brought about a 6.59% increase in the Iowa ethanol prices. Their analysis refers to the period 2007–2009. A strong positive correlation between the ethanol and gasoline prices was also confirmed by Eidman (2005). Tokgoz and Elobeid (2007) analyze the price linkage between the ethanol and gasoline markets employing the non-spatial multi-market partial equilibrium international ethanol model for the United States, Brazil, and European Union-15. They focused on the substitution and complementary relationship between the two fuels. According to the results, ethanol is mainly used as an additive to gasoline and the complementarity relationship is considered to be more dominant than the substitution relationship between ethanol and gasoline in the

[2]Set-aside is an instrument used to reduce the supply of agricultural commodities in order to keep the prices high or to lower export subsidies. Farmers put some land out of production, for which they obtain a compensation from the EU budget.

U.S. Coltrain (2001) found that the ethanol price is typically 50 cents above the price of the wholesale gasoline. Studies by the Clean Fuels Development Coalition (2003) and Gallagher et al. (2003) support this finding, attributing the difference in the ethanol and the wholesale gasoline price to the U.S. federal excise tax. Lau et al. (2004) found the wholesale gasoline price and the federal subsidy level as having a significant effect on the ethanol price.

O'Brien and Woolverton (2009) also find a strong positive correlation of 93% between the gasoline prices and oil prices in the 2007–2009 period. A 10% increase in U.S. domestic oil prices led to about a 6.14% increase in the U.S. Midwest gasoline prices.

Girma and Paulson (1999) investigated the long-run relationship among crude oil and gasoline, and found that the prices are co-integrated. They also found a stationary relation between crude oil and its end products.

In the long-run, oil prices are influencing gasoline prices which then impact ethanol prices. As the global economy expands or contracts, oil prices are affected, placing pressure on gasoline prices which then influence ethanol prices (Zhang et al. 2010). Balcombe and Rapsomanikis (2007) argue that the feedstock, ethanol, and oil prices may be perceived as being non-related if prices move within a threshold, but the price transmission mechanisms may be activated outside the threshold.

Most of the studies on the relationship between oil, gasoline and ethanol prices focus on the U.S. markets and use the U.S. prices. There are no studies focusing on the EU market that we are aware of. To study the relationships between the price of oil and the price of gasoline and ethanol is useful for several reasons. First, knowing the relationship between the oil price and the biofuel price is helpful for forecasting the biofuel prices in the future. Second, if there is a robust confirmation of the strong relationship between oil prices and the biofuel prices, then we can analyze the impact of various trade and agricultural policies on the production of ethanol as well as on the welfare. For example, if the price of oil is exogenous, then the price of ethanol is fixed and related to the price of oil and the imports of biofuels from abroad have no impact on domestic producers of biofuel but they help to fulfill the use of the biofuel mandate.

METHODS AND DATA

The article evaluates the relationship among the following variables: German ethanol prices, German gasoline prices and Europe Brent oil prices. We analyze the strength and direction of a possible linear relationship among the variables. We conduct a series of statistical tests, starting with the tests for unit roots and stationarity, the estimation of cointegrating relationships between the price pairs, the estimation of the linear cointegration and evaluating the inter-relationship among the variables in a Vector Autoregression (VAR) and the Impulse Response Function (IRF). The direction of causation in the variables runs from oil to gasoline to ethanol investigated by means of the Granger causality tests.

We use the weekly data (January, 2000 to October, 2009) for gasoline, oil and biofuel prices. The total number of data points is 484. Prices are expressed in USD per 1 gallon. German ethanol prices come from the Bloomberg database (2000–2009). German gasoline prices and Europe Brent oil prices are from the Energy Information Administration (2000–2009). German prices are used because Germany has been one of the most important ethanol producers in Europe during the observed period. To attain stationarity the series must be transformed. A common way of achieving stationarity is to take logarithms and then first differences. Logarithmic transformation of the prices is used due to the assumed multiplicative effect (Johansen 1995). The use of the logarithm of the variables of the model implies that the corresponding coefficients are now interpreted in percentage terms.

RESULTS

Development of ethanol, gasoline and oil prices

Since early 2000, ethanol prices in Europe have widely fluctuated (Figure 2, Table 1). The highest price in the period reached $3.94 per 1 gallon in March 2008, while the lowest price at the amount of $1.33 per 1 gallon was observed in September 2000. The ethanol market in Europe was growing slowly in 1990s. It took almost 10 years for production to grow from 60 million litres in 1993 to 525 million litres in 2004. A high increase in production has been driven by the combination of the EU biofuel policy, the reduction of production costs, and the increase in oil prices.

Table 1. Descriptive statistics

Variable	Obs.	Mean	SD	Min	Max
Ethanol	484	2.51576	0.72192	1.32716	3.93718
Gasoline	484	1.71238	0.65682	0.70380	3.90654
Oil	484	1.16803	0.62675	0.40142	3.42738

Source: own calculation

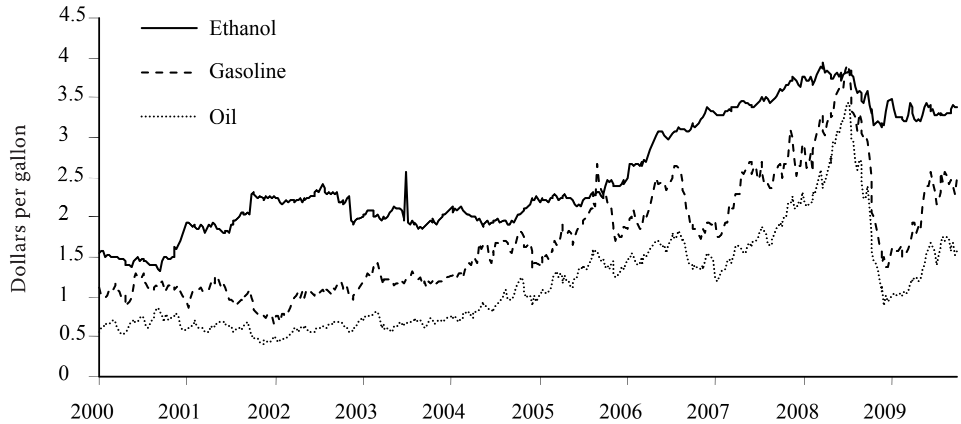

Figure 2. Development of the ethanol, gasoline and oil prices

Source: Bloomberg – ethanol prices, EIA – gasoline prices, oil prices

Around September 2005, the ethanol price dropped below the gasoline price. The same situation was observed in the U.S. ethanol market as well. Hart (2005) attributes this fall in price to the expansion of the ethanol production and to the expansion of ethanol products that directly compete with gasoline, such as E85[3]. There was an explosion in production in 2005 and 2006 with double-digit growth rates.

Ethanol prices were growing in the observed period, however. The growth of the ethanol prices, especially after 2004, coincided with the growth of oil prices. Oil prices reached the peak in July 2008. Oil being the raw product from which gasoline is produced, it has also a crucial impact on the development of gasoline prices. 2008 was also the year when the ethanol production in Europe reached another peak, increasing significantly by 56%, from 1.8 billion in 2007 to 2.8 billion in 2008.

A look at the price differentials for gasoline and ethanol (Figure 3) indicates that in the past, the ethanol price was higher than the gasoline price (except for September 2005 and July 2008). The differentials below zero represent time periods when ethanol is more expensive than gasoline. Other studies

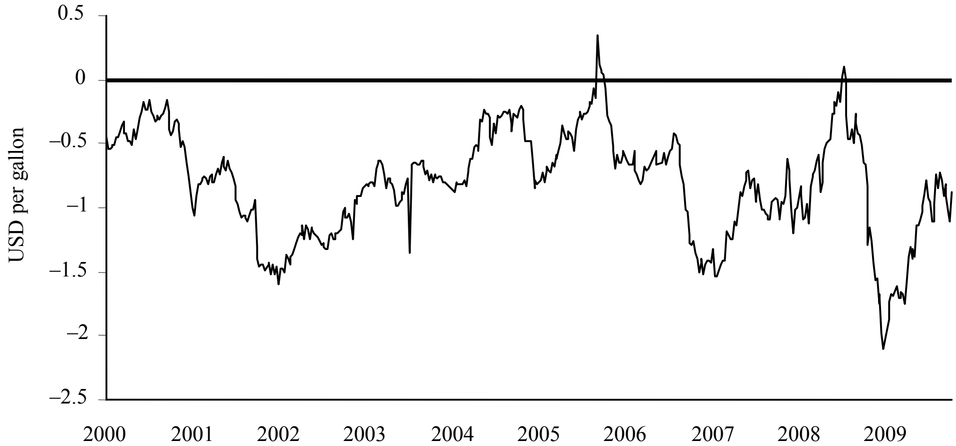

Figure 3. Gasoline ethanol differential

Source: Bloomberg – ethanol prices, EIA – gasoline prices (gasoline – ethanol differential without the taxes and tax credit)

[3]E85 is an alcohol fuel mixture that typically contains a mixture of up to 85% denatured fuel ethanol. Low ethanol blends from 5 to 22% of ethanol can be applied without modifications of the engines and with the existing infrastructure. Blends of 10% ethanol and 90% gasoline are used in the USA and Brazil and are denoted as E10. E5, which is a blend containing 5% of ethanol and 95% gasoline, is often used in the European countries. High ethanol blends of 85% of ethanol content in gasoline can also be used. They require special engine modifications and have been widely used in flexible fuel vehicles (FFV) that are adjusted for the application of any blend of biofuel and ordinary fuel.

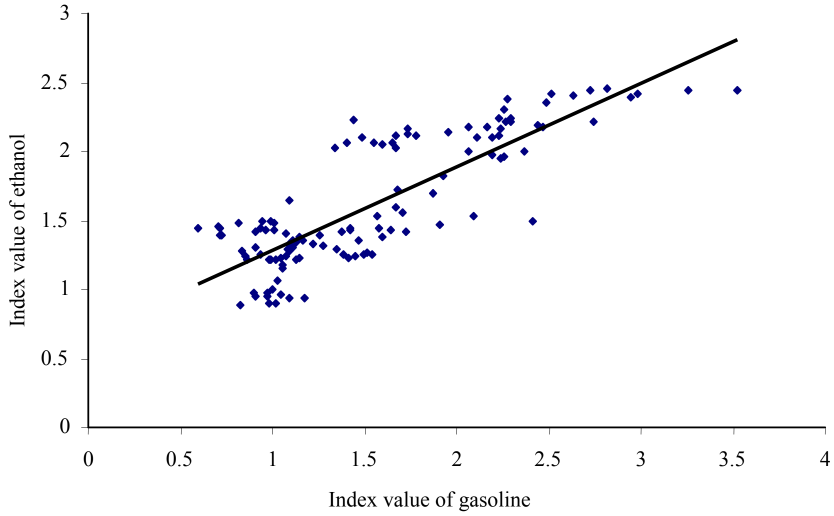

Figure 4. Ethanol gasoline price relationship (index Jan 2000 = 1)

Source: Bloomberg – ethanol prices, EIA – gasoline prices

have shown similar results, showing that ethanol is not competitive with gasoline without government policies (Kruse et al. 2007; de Gorter and Just 2008; Hermanson 2008).

The correlation analysis confirms a high and positive correlation between the ethanol and gasoline prices. The correlation between the ethanol and gasoline prices was 83.56% (Table 2). As expected, there is also a very high and positive correlation between the oil and gasoline prices (97.8%).

Figure 4 shows a scatter diagram of the monthly index of ethanol and gasoline prices since January 2000. The straight line represents a regression of the ethanol prices on gasoline prices. The price series do not move with an exact precision over the time, still there exists a strong relationship between the two price series. However, this may be a result of the spurious correlation if the price series are not stationary.

Table 2. Correlation Matrix

Variable	Ethanol	Gasoline	Oil
Ethanol	1.0000	–	–
Gasoline	0.8356	1.0000	–
Oil	0.8345	0.9780	1.0000

Source: own calculation

Stationarity of the time series

Non-stationary time series can lead to statistically significant results due to a purely spurious correlation. We therefore tested for the stationarity of the ethanol, oil and gasoline price series.

We use three tests to check for the stationarity of time series: the augmented Dickey Fuller (ADF) test, the Phillips Perron (PP) test, and the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS).

The lags of the dependent variable were determined by the Akaike Information Criterion (AIC).

All tests (Tables 3 and 4) show that the time series (oil, gasoline and ethanol) are integrated of order 1, i.e. non-stationary. The order of integration refers to

Table 3. Unit root tests

Time series	Level			First differences		
	none	constant	constant and trend	none	constant	constant and trend
ADF – ethanol	1.315	–1.184	–1.731	–13.697***	–13.841***	–13.839***
ADF – gasoline	–0.497	–1.613	–3.186	–10.090***	–10.111***	–10.100***
ADF – oil	–1.322	–1.359	–2.294	–14.449***	–14.455***	–14.439***
PP – ethanol	1.167	–1.135	–2.952	–26.420***	–27.334***	–27.312***
PP – gasoline	–0.415	–1.421	–3.084	–22.781***	–22.785***	–22.762***
PP – oil	–1.395	–1.438	–2.059	–20.448***	–20.491***	–20.470***

*significance at the 10% level; **significance at the 5% level; ***significance at the 1% level

Source: own calculation

Table 4. Stationarity test

Time series	Level – stationarity		First differences – stationarity	
	level	trend	level	trend
KPSS – ethanol	10.3	0.86	0.0782***	0.0707***
KPSS – gasoline	7.97	0.493	0.0404***	0.0382***
KPSS – oil	13.2	1.02	0.0581***	0.0544***

*significance at the 10% level; **significance at the 5% level; ***significance at the 1% level

Source: own calculation

the number of times a variable is differenced before becoming stationary. To make them stationary, we therefore take the first differences.

Co-integration

The above stationarity tests show that the original time series are non-stationary and could be used for the cointegration test. While the individual time series may be non-stationary, a combination of two non-stationary time series may be stationary (Engle and Granger 1987). In such a case, these individual time series are said to be co-integrated. If two time series are co-integrated, there exists a long-run equilibrium relationship between them and the ordinary least squares can be used to estimate the parameters of their relationship.

We use the ADF test on residuals from the original time series (known also as the augmented Engle-Granger (AEG) test) and the Johansen test to check for the co-integration of time series. The AEG test (Engle and Granger 1987) assumes that there is a unique co-integrating relationship (Menon 1993).

The results of the AEG test are reported in Table 5. Table 5 shows that the residuals from the regression of gasoline on oil are I(0), i.e. they are stationary. This means that the regression of gasoline on oil is a co-integrating regression, not a spurious one, although individually the time series are non-stationary. On the other hand, the residuals from the other two regressions (ethanol on oil and ethanol on gasoline) are non-stationary, the original time series are therefore not co-integrated and we use their first differences when regressing ethanol on gasoline and ethanol on oil.

Table 5. Augmented Dickey Fuller test for residual series

Time series	Residual series
Ethanol – oil	–2.377
Ethanol – gasoline	–2.237
Gasoline – oil	–5.241***

Source: own calculation

The Johansen Cointegration Test allows for testing the co-integration of several time series. This test furthermore does not require time series to be of the same order of integration. In the Johansen Co-integration Test, the co-integration rank (number of the co-integration relationships) is obtained through the trace test. In the Johansen co-integration test, we used the 1% level of significance because the power of this test is low. As shown in the Table 6, gasoline and crude oil time series are co-integrated as expected.

Both the Johansen test and the AEG test lead to the same conclusions: gasoline and oil time series are co-integrated, while other time series are not co-integrated.

On the contrary, Higgins et al. (2006) found the co-integration relationship for ethanol and gasoline but also ethanol and natural gas and ethanol and the MTBE using the U.S. data for the period from 1989 to 2005. Zhang (2009) also confirmed the co-integrating relationship among the U.S. fuel prices (gasoline, oil, and ethanol). However, this relationship was observed only in the ethanol boom period (2000–2007). No co-integrating relationship existed between the ethanol and oil prices before 2000 in the USA. The only co-integration was found between the gasoline and oil prices in 1989–1999.

Cointegration tests in Serra (2008) support the existence of a (single) long-run relationship between ethanol, corn and oil prices. A high degree of integration between the biofuel and the fossil fuel markets should ensure a strong price link between the two products. There are, however, different constraints that can limit such integration: bottlenecks in dis-

Table 6. Johansen co-integration test

Rank	Trace statistic	1% critical value
Ethanol – oil		
0	7.5953	20.04
1	1.0257	6.65
Ethanol – gasoline		
0	6.7402	20.04
1	1.0608	6.65
Gasoline – oil		
0	39.093	20.04
1	1.6961	6.65
Ethanol – gasoline – oil		
0	49.197	35.65
1	9.9659	20.04
2	3.5420	6.65

Source: own calculation

tribution, technical problems in transportation and blending systems, etc. (Serra et al. 2008)

Vector Autoregression model

To estimate the parameters of the relationship between oil, gasoline and ethanol price time series, we used the Vector Autoregression (VAR) model because not all of the variables were co-integrated. We estimated the VAR(2) model on the first differences of the logarithms of each variable. Table 7 presents the main results of the model (*p*-values are presented in parentheses below the estimates).

First, we found a relationship between the price of gasoline and ethanol. The coefficient 0.068993 implies that if the gasoline price in the period $t-1$ goes up by one unit, the ethanol price in the period t would go up by 0.068993. Both prices are positively linked.

Second, we found a relationship between the gasoline and oil prices. If the price of gasoline in period $t-1$ increases by one unit, the coefficient shows that oil price in period t increases by 0.1499384. The same is valid for the price of gasoline in the period $t-2$ and oil price in the period t. The increase of gasoline price in the $t-2$ period by one unit increases the oil price in the t period by 0.1069034.

Next, we found a relationship between the oil price and ethanol price. However, the coefficient –0.0540094 implies, that an increase in oil price in the period $t-2$ by one unit leads to a decrease in the ethanol price by 0.0540094.

The strongest is the relationship observed between the oil prices and the gasoline prices. The model suggests that the increase in the oil price by one unit in the period $t-1$ and $t-2$ will lead to an increase in the gasoline price by 0.4288639 and 0.1677313 respectively. Finally, we found that each variable in this period is affected by its own values from the previous periods.

To check the suitability of the model, we tested the presence of the autocorrelation, the joint significance of the VAR coefficients at various lags as well as the Eigenvalue stability condition, whether the VAR model satisfies the stability condition. As a result, all the eigenvalues lie inside the unit circle and the VAR satisfies the stability condition, the VAR coefficients are jointly significant and no auto-correlation at the lag order was observed.

We needed to run a causality test in order to explore if there is a "Granger causality" among the analyzed variables. A Wald test is commonly used to test for the Granger causality. Each row of the table reports a Wald test that the variable in the "excluded" column does not Granger cause the variable in the "equation" column.

The Granger causality tests highlight the presence of at least unidirectional causality linkages as an indication of some degree of integration. This implies that each market uses the information from the other when forming its own price expectations, while the unidirectional causality informs about the leader-follower relationships in terms of price adjustments (Arshaad and Hameed 2009). Causality tests answer the question which of the observed commodities is a price leader and which are the price followers, or that none of the commodities is more important than the other (Ciaian and Kancs 2009). The fundamental Granger causality method is based on the hypothesis that the compared series are stationary or I(0). In the absence of the co-integration vector, with I(1) series, valid results in the Granger causality testing are obtained by simply first differentiating the VAR model. Hassapis et al. (1999) show that in the absence of co-integration, the direction of causality can be decided upon via the standard *F*-tests in the first differenced VAR.

X Granger causes *Y*, if the past values of *X* can help to explain *Y*. Of course, if the Granger causality holds, this does not guarantee that *X* causes *Y*. This is why we

Table 7. Vector autoregression

	Ethanol	Gasoline	Oil
Ethanol L1	–0.2484576 (0.000)	–0.0574191 (0.483)	–0.0701044 (0.463)
Ethanol L2	–0.1003702 (0.027)	–0.0677275 (0.404)	0.045901 (0.628)
Gasoline L1	0.068993 (0.009)	–0.2206276 (0.000)	0.1499384 (0.007)
Gasoline L2	0.0303603 (0.208)	–0.0416184 (0.334)	0.1069034 (0.033)
Oil L1	–0.027945 (0.213)	0.4288639 (0.000)	0.0256903 (0.583)
Oil L2	–0.0540094 (0.030)	0.1677313 (0.000)	–0.0457989 (0.377)

p-values in parentheses below the estimate

Source: own calculation

Table 8. Granger causality Wald tests

Equation	Excluded	Prob > chi^2
Ethanol	gasoline	0.024
Ethanol	oil	0.051
Ethanol	all	0.066
Gasoline	ethanol	0.610
Gasoline	oil	0.000
Gasoline	all	0.000
Oil	ethanol	0.618
Oil	gasoline	0.006
Oil	all	0.030

Source: own calculation

say the "Granger causality" rather than just "causality". Nevertheless, if the past values of *X* have an explanatory power for the current values of *Y*, it at least suggests that *X* might be causing *Y* (Koop 2006).

Causality results are reported in Table 8. As seen from the table, we found a casual relationship between gasoline and ethanol and oil and ethanol, even if the results are only significant at 5.1% level. As expected, the price of ethanol does not Granger cause the prices of gasoline and oil. However, there is a bivariate causal relationship between the gasoline and oil prices. This feedback relationship between the oil and gasoline prices is strong with a significance level of one percent. Similar results were found by Zhang et al. (2010), where in the long-run, oil prices are influencing gasoline prices which then impact ethanol prices.

Zhang (2009) explains that the increases in the price of gasoline are driving up the ethanol and oil prices. Gasoline prices not only directly influence oil prices but also indirectly influence them by impacting the ethanol prices which influence oil prices.

Impulse Response Function

Impulse Response Functions were performed in order to show how a shock in one variable would persist in the future periods. The forecast was made considering a ten-week period.

As we can see from Figure 5, a shock in the ethanol price would result in a temporary response in the gasoline and oil prices. The sudden increase in ethanol price would result in a slight decrease of the gasoline and oil prices. It seems that the response disappears after about two weeks. This is also true

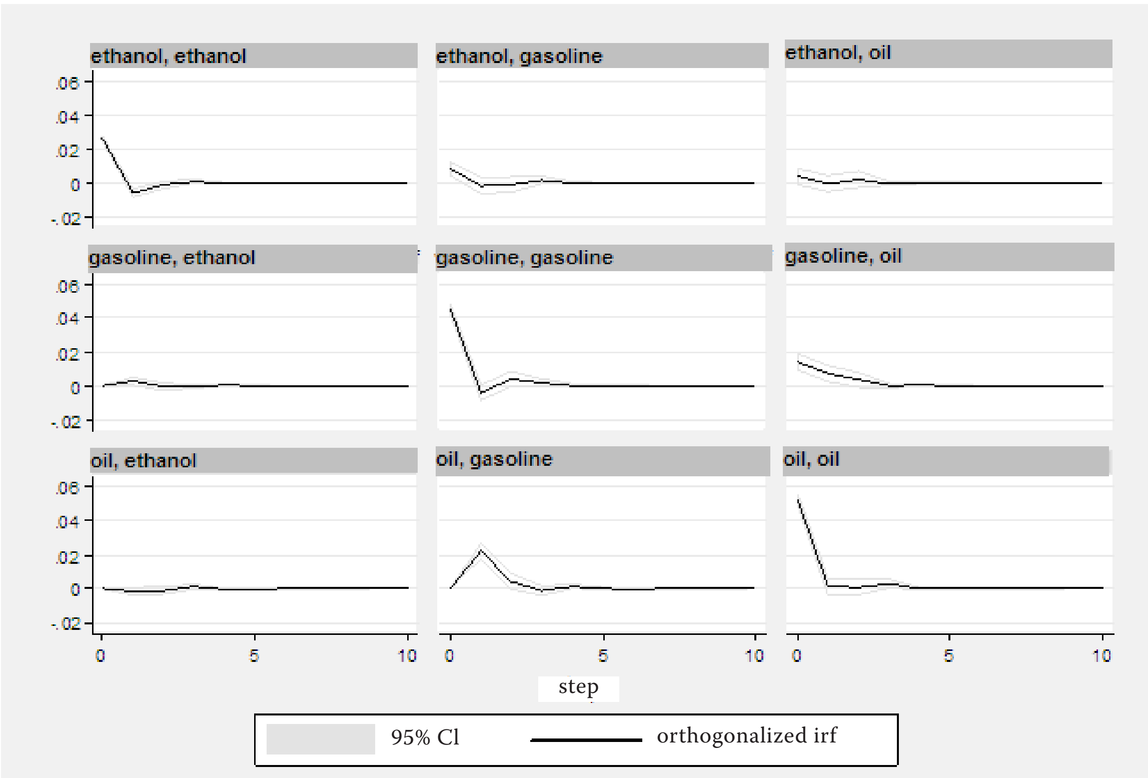

Figure 5. Impulse Response Function

Order of variables: impulse variable, response variable

Source: own calculation

for the response of the oil price to the shock in the gasoline prices. As Figure 5 shows, a sudden change in oil prices results in a small change in the ethanol prices, but the same shock in oil prices will lead to a strong response of the gasoline prices. After a sudden increase, the gasoline prices will then start decreasing after 7–10 days following the shock. It will eventually approach zero within a ten-week period, which proves to be a temporary response.

Similar results were observed by Serra (2008). The ethanol responses usually reach a peak after about 10 days of the initial shock and fade away after around 30–35 days (Serra et al. 2008).

CONCLUSION

The main purpose of this paper is to analyze the statistical relationship between ethanol, gasoline and crude oil prices. In order to achieve our goal, we first collected weekly data for each variable from January, 2000, to October, 2009. The results provide the evidence of the co-integration relationship between the oil and gasoline prices, but no co-integration between ethanol, gasoline and ethanol, oil prices. As a result, we used a VAR model on first differences. We found a relationship between the price of gasoline and ethanol, gasoline and oil prices, oil price and ethanol price and the strongest is the relationship observed between the oil prices and gasoline prices.

After running an Impulse Response Function, we found out that the impact of the oil price shock on the other variables is considerably larger than vice versa. The largest impact of the oil price shock was observed on the price of gasoline. All the responses will eventually approach zero within a ten-week period, which proves to be a temporary response.

REFERENCES

Arshad F.M., Hameed A.A.A. (2009): The long run relationship between petroleum and cereals prices. Global Economy & Finance Journal, *2*: 91–100.

Balcombe K., Rapsomanikis G. (2007): Bayesian Estimation and Selection of Nonlinear Vector Error Correction Models: The Case of the Sugar-Ethanol-Oil Nexus in Brazil. Working paper, Department of Agricultural and Food Economics, University of Reading, Reading. Available at http://www.personal.rdg.ac.uk/~aes05kgb/Thresholdpaper_revised_September06.pdf (accessed March 2010).

Ciaian P., Kancs A. (2009): Interdependencies in the Energy-Bioenergy-Food Price Systems: A Cointegration Analysis. EERI Research Paper, Series No. 06/2009; ISSN: 2031-4892.

Clean Fuels Development Coalition (2003): Ethanol Fact Book: A Compilation of Information about Ethanol. Clean Fuels Development Coalition, Bethesda, MD.

Coltrain D. (2001): Economic issues with ethanol. In: Kastens T. (ed.): Risk and Profit Management Conference Proceedings. Kansas State University, August 16–17, Manhattan, KS.

de Gorter H., Just D.R. (2008): Water in the U.S. Ethanol Tax Credit and Mandate: Implications for Rectangular Deadweight Costs and the Corn-Oil Price Relationship. AAEA Annual Meeting in New Orleans, LA, January.

Eidman V.R. (2005): Agriculture as a Producer of Energy. In: Collins K.J., Duffield J.A., Outlaw J. (eds.): Agriculture as a Producer and Consumer of Energy. CABI Publishing, Cambridge, MA.

Engle R.F., Granger C.W.J. (1987): Co-integration and error correction: representation, estimation, and testin. Econometrica, *55*: 251–276.

Gallagher P.W., Shapouri H., Price J., Schamel G., Brubaker H. (2003): Some long-run effects of growing markets and renewable fuels standards on additive markets and the US ethanol industry. Journal of Policy Modeling, *25*: 585–608.

Girma P.B., Paulson A.S. (1999): Risk arbitrage opportunities in petroleum futures spreads. Journal of Futures Markets, *18*: 931–955.

Hart C.E. (2005): Ethanol Revisited. Iowa Ag Review, Center for Agricultural and Rural Development. Iowa State University, Summer.

Hassapis N.P., Prodromidis K. (1990): Unit roots and Granger causality in the EMS interest rates: the German dominance hypothesis revisited. Journal of International Money and Finance, *18*: 47–73.

Hermanson D. (2008): The Impact of Biofuel Production on Energy and Agricultural Price Relationships. [Msc. Thesis.] Ohio State University.

Higgins L., Bryan H., Outlaw J., Richardson J. (2006): Ethanol pricing: explanations and interrelationships. Selected paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting Orland, Florida, February 5–8.

Jeníček V., Krepl V. (2009): Energy and the European Union. Agricultural Economics – Czech, *55*: 1–11.

Johansen S. (1991): Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica, *59*: 1551–1580.

Johansen S. (1995): Likelihood-based inference in cointegrated vector autoregressive models. Oxford University Press; ISBN13: 978-0-19-877450-1, ISBN10: 0-19-877450-8.

Koop G. (2006): Analysis of Financial Data. John Wiley & Sons Ltd, England; ISBN-13 978-0-470-01321-2.

Kruse J., Westhoff P., Meyer S., Thompson W. (2007): Economic impacts of not extending biofuel subsidies. AgBioforum, *10*: 94–103.

Lau M.H., Outlaw J.L., Richardson J.W., Herbst B.K. (2004): Short-Run Density Forecast for Ethanol and MTBE Prices. Paper presented at the 2004 Agriculture as a Producer and Consumer of Energy Conference, Washington D.C., 24–25 June 2004.

Menon J. (1993): Import Price and Activity Elasticites for the MONASH Model: Johansen FIML Estimation of Cointegration Vectors. Working Paper, Center of Policy Studies and Impact Policy, Monash University, Australia.

O'Brien D., Woolverton M. (2009): The Relationship of Ethanol, Gasoline and Oil Prices. AgMRC Renewable Energy Newsletter, July 2009.

Serra T., Zilberman D., Gil M.J., Goodwinc B.K. (2008): Nonlinearities in the US corn-ethanol-oil price system. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Orlando, FL, July 27–29, 2008. Available at http://ageconsearch.umn.edu/handle/6512 (accessed March 2010).

Tokgoz S., Elobeid A. (2007): Understanding the Underlying Fundamentals of Ethanol Markets Linkage between Energy and Agriculture. Paper presented at the American Agricultural Economics Association Annual Meeting, Portland, OR, 29 July–1 August, 2007.

Zhang Z., Lohr L., Escalante C., Wetzstein M. (2010): Food versus fuel: What do prices tell us? Energy Policy, *38*: 445–451

Zhang Z., Lohr L., Escalante C., Wetzstein M. (2009): Ethanol, corn, and soybean price relations in a volatile vehicle-fuels market. Energies, *2*: 320–339; doi:10.3390/en20200320.

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